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(54) IMPROVEMENTS IN AND RELATING TO DISPLAY DEVICES

(71) We, MATSUSHITA ELECTRIC INDUSTRIAL COMPANY LIMITED, a Japanese company, of 1006 Oaza Kadoma, Osaka-fu, Kadoma-shi, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a display or display and recording device, hereinafter referred to, for brevity, as a display device.

The invention includes a display device comprising a layer, including a luminescent material, the luminescent appearance of the device being controllable by electrophoretic movement of an electrophoretic material in said layer.

The invention also includes a display device comprising a layer including a suspension medium and at least one material in a form susceptible of electrophoretic mobility suspended in said medium, at least one of the components of said layer being luminescent, and at least one of the components of said layer being substantially opaque to the radiation which excites the luminescence or to visible light, said suspension being bounded by opposed surfaces, spaced electrodes positioned with respect of said surfaces whereby on applying an electric field across said layer between said electrodes, the spatial distribution of said electrophoretic material between said surfaces is electrophoretically changed whereby to change the luminescent appearance to said device.

The invention makes possible a luminescent display device having a large and/or flat or curved display panel. The panel can be flexible.

Other features and advantages of the invention will be apparent from the following description of embodiments thereof, given by way of example, and the accompanying drawings, in which:—

Figures 1*a*, 1*b* and 1*c* are diagrammatic cross-sectional views of a display panel;

Figures 2*a* and 2*b* are cross-sectional views of another form of display panel;

Figures 3*a* and 3*b* are diagrammatic cross-sectional views of another form of display panel;

Figures 4*a* and 4*b* are diagrammatic cross-sectional views of another form of display panel;

Figure 5 is a diagrammatic perspective view, part broken away, of a form of display panel;

Figure 6*a* is a diagrammatic front view of an electrode for use in monogrammic character display panel;

Figure 6*b* is a diagrammatic cross-sectional view of the panel of Figure 6*a*;

Figure 6*c* is a diagrammatic front view of an alternative form of the electrode of Figure 6*a*;

Figure 7 is a diagrammatic perspective view, partially broken away, of an image display panel;

Figures 8*a*, 8*b* and 8*c* are diagrammatic cross-sectional views of an electrostatic image display panel according to this invention;

Figure 9 is a diagrammatic cross-sectional view of another form of image display device;

Figure 10 is a diagrammatic cross-sec-

tional view of an electrostatic image display;

Figure 11 is a diagrammatic cross-sectional view of a display panel;

Figures 12*a* and 12*b* are diagrammatic cross-sectional views of a form of display panel;

Figure 12*c* is a diagrammatic front view of a display panel;

Figure 13 is a diagrammatic perspective view of a member for use in the panel of Figure 12; and

Figure 14 is a diagrammatic cross-sectional view of another form of display device.

In the drawings, the size and shapes of elements are not to scale and numerous elements have been purposely distorted in size or shape for clarity.

Referring to Figure 1*a*, reference character 20 designates a luminescent display or display and recording panel which includes a luminescent electrophoretic suspension layer 21.

The suspension layer 21, in a fluid state, is contained within a housing 22 formed of a frame 23 and two opposed major housing walls 24 and 25 of material transparent to radiation flux and visible light.

The suspension layer 21 presents two opposed major surfaces extending along the surfaces of the housing walls 24 and 25. The suspension includes a dispersion of at least one electrophoretic material 26 in a finely divided powder form suspended in a suspension medium 27; the particles of the material 26 are shown greatly enlarged in this and subsequent Figures. The two surfaces of the suspension layer 2 are in contact respectively with first and second electrodes 28 and 29, which are of material transparent to radiation flux and visible light; the electrodes are attached to the inner surfaces of the housing walls 24 and 25.

The electrodes 28 and 29 are mounted to the terminals of a direct voltage source 30 through a switching means 31. If no electric field is imposed on the suspension layer from said source 30, the finely divided electrophoretic material is distributed uniformly throughout the suspending medium 27 as shown diagrammatically in Figure 1*a*.

Radiation sources 32 and 33, for example ultra-violet light sources, are positioned on opposite sides of the panel so as to direct radiation flux on both sides of the suspension layer. If the electrophoretic material 26 is luminescent and emits, for example, green light when excited by ultra-violet light and the suspension medium 27 is not luminescent and strongly absorbs the visible light and/or the radiation flux, the suspension layer 2 exhibits a deep green colour at electrodes 28 and 29 in response to the radiation.

If the deep green suspension layer is subjected to a unidirectional electric field by voltage from source 30, the electrophoretic material is caused to move electrophoretically in a direction toward the cathode or the anode, depending upon its polarity. For example, if the material is negatively charged, it moves and is deposited on the anode 28. A non-uniform spatial distribution results as shown diagrammatically in Figure 1*b*.

This different spatial distribution of the material 26 results in a luminescent appearance differing from that of the original suspension layer of uniform distribution. For example, the panel may show a bright green colour at the anode because the green light emitted in response to source 32 from the layer of the electrophoretic material deposited on the anode is directly visible through the anode 28 without transmission through and absorption by the suspension medium 27. The cathode side of the panel is dark, since light emitted from the electrophoretic material adjacent the anode is absorbed on transmission through the suspension medium. Reversal of the direction of the field by reversing the polarity of the applied voltage, causes the electrophoretic material to be deposited on the cathode 29, as shown in Figure 1*c*, and a reversal of the colour characteristic of the panel.

The foregoing description assumes that the suspension medium is not luminescent, but this may not be so, and a luminescent suspension medium can be used. In this case, the panel may exhibit, at its surfaces, colours which are additive mixtures of the luminescent colours of the medium and the electrophotoretic material. The device of Figure 1*b* or Figure 1*c* will show, at electrode 28, colours which are substantially the luminescent colours of the electrophoretic material or the suspension medium respectively. The colour characteristic of the panel depends upon the spatial distribution of the electrophoretic material, the luminescent properties of the electrophoretic material and the suspension medium and transmission properties of the electrophoretic material and the suspension medium for radiation flux and visible light. In this way, when the device is exposed to the radiation flux its luminescent appearance will change due to electrophoretic movement of the material 26.

If only a small amount of the electrophoretic material is deposited on the anode, a half-tone appearance is produced at the anode side of the panel dependent upon the amount of material deposited electrophoretically on the anode. Hence the colour characteristic at the anode side of the panel

is subject to continuous control by control of the amount of material deposited electrophoretically on the electrode, and this can be controlled by the direction, magnitude or period of application of the voltage. Since the colour at the cathode side of the panel is affected by the electrophoretic movement of the electrophoretic material toward the anode, the colour of the display panel can be changed by varying the magnitude, the duration and the polarity of the applied electric field.

Electrophoretic material deposited on an electrode surface by electrophoresis will remain on the electrode after the removal of the applied electric field, and this means that the display device described serves to record information without the sustained use of electric field or power. The panel can be restored to its original colour by an appropriate electric field of reverse polarity or by the application of strong mechanical vibrations to the device. An applied A.C. electric field to the suspension layer can also effectively restore the original colour of the panel.

With the device shown in Figure 1, changes of the luminescent appearance of the suspension layer can be observed from both sides of the panel since the radiation sources are positioned one on each side of the panel, and two walls of the housing and the two electrodes are all transparent to radiation flux and visible light. If it is desired to observe the device from one side only the other housing wall and the attached electrode can be replaced by an opaque conductive plate such as a metal plate for example, and the corresponding radiation source omitted. A suspension layer comprising a luminescent suspension medium and at least one luminescent or non-luminescent electrophoretic material suspended in the luminescent suspension medium can also be used. At least one of the components of the suspension layer, that is the suspension medium or the electrophoretic material, must be luminescent and another component must be substantially opaque to the radiation flux and/or visible light emitted from the one luminescent component. The desired opacity can be due to absorption and/or reflection of the radiation flux or visible light.

In another form of the device a radiation source is disposed behind the panel and visible light is emitted from the front. When a device of this type is observed through the electrode 28, for example, the radiation source 32 is removed and the housing wall 24 and the electrode 28 must be transparent to visible light and the housing wall 25 and the electrode 29 must be transparent to the radiation flux. The operation of such a device can be explained with reference to Figures 1*a*, 1*b* and 1*c*. If the electrophoretic material is luminescent and the suspension medium is non-luminescent and strongly absorbs light emitted from the electrophoretic material but transmits the radiation flux without substantial absorption, the brightness of the device with the same spatial distribution of the electrophoretic material as indicated in Figures 1*a*, 1*b* and 1*c* is medium, high and low, respectively. On the other hand, if the non-luminescent suspension medium does not substantially absorb the light emitted from the electrophoretic material but strongly absorbs the radiation flux, the brightness of the device in the conditions of Figures 1*a*, 1*b* and 1*c* is medium, low and high, respectively. Thus, the colour characteristic of such a device at the side opposite the radiation source can be changed by application of a suitable direct voltage. There can also be used suspension layers in which the suspension medium is also luminescent, or the electrophoretic material is non-luminescent but the suspension medium is luminescent. When there is only one luminescent component in the suspension layer another component in the suspension layer must be substantially opaque to radiation flux or visible light emitted from the luminescent component.

A device in which the radiation source is located behind the panel is useful for many display purposes as it does not require a large space in front of the panel.

The unidirectional voltage for controlling the electrophoretic material need not be a constant direct voltage and may be any other unidirectional voltage such as a pulse voltage or pulsating voltage.

The radiation flux for activating the luminescent suspension layer can be any of a number of suitable sources: in addition to ultra-violet light there can be used visible light, x-ray, γ-ray, electron beam or α-particles. Such luminescence phenomena are usually called photoluminescence, radioluminescence or cathodoluminescence, respectively. Examples of ultra-violet sources include fluorescent lamps, mercury lamps, xenon lamps or sun light.

Ultra-violet fluorescent lamps such as, for example, a lamp radiating in a range about 2537Å, chemical lamp radiating ultra-violet light of about 3000Å or a black light lamp radiating ultraviolet of about 3600Å are convenient to use. By positioning several lamps behind the display panel a relatively slim display device can be made, emitting visible light information from the front of the panel.

It is not necessary that the radiation source should be positioned outside the suspension layer, and the source can be disposed inside the layer. Radioactive isotopes

such as, for example, radium, strontium 90, tritium or promethium 147 radiate suitable flux such as α-particles or electrons. If the suspension layer includes a suitable radioactive isotope and at least one luminescent component capable of radiation visible light by the radiation flux from the isotope, the device is self-luminescent and no external source of radiation is required.

The means for activating the suspension layer is not restricted to a radiation source, and the layer can be made to emit visible light by excitation by an electric field applied across the suspension layer, that is by electroluminescence. When the electrophoretic suspension layer includes at least one component consisting of an electroluminescent material in the suspension layer, an electric field applied across the suspension layer will cause the electroluminescent material to emit visible light. The electric field for this purpose can be any suitable time-varying field, including an alternating electric field, a repetitive pulse field or a pulsating field. When the electrophoretic material consists of an electroluminescent material, the suspension layer can be made to emit light upon application of, for example, an A.C. voltage from the voltage source 30 applied between the electrodes 28 and 29 in Figure 1. An electric field applied across the suspension layer to control its brightness can change the spatial distribution of the electrophoretic material in the suspension medium established by application of the unidirectional voltage. For example, a spatial distribution of electrophoretic material such as that shown in Figures 1*b* or 1*c* established by the application of a unidirectional voltage may be destroyed by an alternating field applied from the voltage source 30, to control the brightness of the suspension layer, and change it to the distribution of electrophoretic material as indicated in Figure 1*a*. This change in the spatial distribution of the electrophoretic material depends upon the magnitude, the duration and the frequency of the alternating voltage applied. If the electrophoretic material suspended in the suspension medium follows the frequency of the applied alternating voltage to the extent of vibrating between the electrodes, the device emits light, at both electrodes, cyclically varying at the frequency of the applied voltage.

On the other hand, if the suspension layer having a spatial distribution of the electrophoretic material as shown in Figure 1*a* is subjected to, for example, repeated unidirectional pulse voltages from the voltage source 30, the negative electrophoretic material, while emitting light, moves toward an anode under the influence of the pulse voltage and is deposited on the anode surface, whereby the device emits electroluminescent light at the anode. In consequence, a device having a suspension layer in a liquid state brightened by an electric field having a direct component, cannot produce a stationary half-tone display because the applied voltage deposits all of the electrophoretic material on the one electrode. If, as described hereinafter, the suspension layer is hardened after the desired spatial distribution of the electrophoretic material is established by the unidirectional field, application of any electric voltage from the voltage source 30 across the suspension layer to control the brightness of the suspension layer can maintain the desired colour of the display without changing the spatial distribution of the electrophoretic material in the suspension medium.

The suspension layer may also consist of an electroluminescent electrophoretic material suspended in an electroluminescent suspension medium. If the colour of the light emitted by electrophoretic and suspension mediums differ in hue and/or saturation, the colour characteristic of the display can be varied over a wide range by varying the polarity of, for example, a repetitive pulse voltage applied across the suspension layer. The electroluminescent suspension medium can be prepared by, for example, suspending an electroluminescent non-electrophoretic material in non-electroluminescent suspension medium. In the present specification, the expression "suspension medium" includes not only a single phase liquid or solid medium but also a suspension comprising non-electrophoretic particles suspended in a liquid or solid medium.

The suspension medium opaque to visible light can be prepared by dissolving a coloured substance, such as a dye, in a colourless liquid, or by suspending electrically neutral coloured particles, such as dyes or pigments, in a colourless liquid. As an example, a deep blue suspension medium can be prepared by dissolving oil black dyes in ethyl acetate or kerosene.

Figures 2*a* and 2*b* show another form of display means: in these and in subsequent Figures, similar parts bear similar references. In Figure 2 a luminescent or non-luminescent porous layer is inserted in a suspension medium 36. The suspension medium 36, the porous layer 35 and the electrophoretic material 26 together make up a luminescent electrophoretic suspension layer 37. Merely to facilitate explanation, it is assumed that the suspension medium 36 is non-luminescent and transparent with respect to radiation flux and visible light. In the device of Figure 2*a*, when the device is subjected to radiation flux on both

its surfaces, a luminescent colour will be produced which is a mixture of the luminescent colour of the electrophoretic material 26 and that of the luminescent porous layer 35, if the porous layer is luminescent and the colour can be seen from both electrodes. In Figure 2 and subsequent Figures the radiation sources are omitted.

If for example the porous layer emits red light when subjected to ultra-violet light, the display device emits yellow light at both electrodes, being an additive mixture of the red luminescent light of the porous layer 35 and the green light of the electrophoretic material. If a unidirectional electric field is applied between the two electrodes 28 and 29, the electrophoretic material is caused to pass through the porous layer and to be deposited on one electrode, depending upon its polarity, for example the anode, as shown in Figure 2*b*. Also, for ease of explanation, it is further assumed that the display is observed from one side only, that is from the side of wall 24 and that the radiation is directed against that side only; in such an arrangement the housing wall 25 and electrode 29 could be replaced by an opaque electrode such as for example, a metal plate. If the layer of electrophoretic material 26 deposited on anode 28 is opaque to the radiation flux and/or the light emitted from porous layer 35, the device in the example given will show the green colour of the electrophoretic material. With a direct voltage of opposite polarity applied between electrodes 28 and 29, the electrophoretic material is caused to pass through the porous layer 35 and to be deposited on the electrode 29. If the porous layer is substantially opaque to the radiation flux and/or the light emitted from the electrophoretic material, the red light emitted from the porous layer in response to the radiation will be seen. Thus, the colour characteristic of the device can be changed from green through yellow, to red, or vice versa, depending upon the polarity of the applied direct voltage.

In another arrangement, the radiation source is arranged behind the panel, as source 33, and no radiation is directed against the wall 24, from which side the device is observed. If the porous layer 35 and the electrophoretic material 26 are opaque to radiation flux but transparent to visible light, or are opaque to visible light but transparent to radiation flux, the colour characteristic of the device can be changed from the green, through yellow to red, or vice versa, again depending upon the polarity of the applied direct voltage. It is not always necessary that the porous layer and the electrophoretic material should both be luminescent; if one at least is electroluminescent, the colour characteristic of the device can be changed by varying the polarity of a respective direct voltage pulse or a pulsating electric voltage from voltage source 30.

The porous layer 35 can be made from any luminescent or non-luminescent sheet material in which pores exist or can be produced. The pores must be of a size large enough to permit the particles of electrophoretic material to pass through but must be as small as possible to disturb the transmission of radiation flux or the light emitted from the luminescent component. Suitable materials include cloth or a mesh fabric woven of natural or artificial fibres; a fibroid sheet having thousands of irregular pores; a thin plate with a very large number of very small holes; and a sheet of material of a granular nature bonded with resin or an adhesive agent to form a porous structure.

In the construction of Figure 3*a*, a suspension medium 39 includes at least two kinds of electrophoretic materials 40 and 41 in finely divided powder form. For simplicity of description, it is assumed that the suspension medium 39 is non-luminescent and transparent to radiation flux and visible light. The suspension medium and the materials 40 and 41 together provide a luminescent electrophoretic suspension layer 42. The two materials 40 and 41 differ with respect to charge polarities and luminescent properties. It is not necessary that both of the electrophoretic materials 40 and 41 of the suspension layer should be luminescent. This device displays at its opposite sides a colour which is a mixture of the luminescent colours of the two kinds of electrophoretic materials 40 and 41 when excited by radiation flux or alternating electric field.

If a unidirectional electric field is applied to the electrophoretic suspension layer, the two electrophoretic materials 40 and 41 of different types are caused to move electrophoretically in opposite directions. The material of positive polarity moves towards the cathode and is there deposited, and that of negative polarity moves to and is deposited on the anode, as indicated in Figure 3*b*. If the material of positive polarity emits, for example, green light and the other and negative material emits, for example, red light, a spatial distribution of electrophoretic materials 40 and 41 as indicated in Figure 3*b* will result, producing a green colour at the cathode side and red colour at the anode, since the electrophoretic materials are substantially opaque to radiation flux and/or visible light.

Before the unidirectional electric field is applied the device has a yellow colour at both electrodes, due to uniform spatial distribution of the green-luminescent material

and the red-luminescent material, as indicated in Figure 3*a*.

The colour characteristic of the display or display and device can be reversed by reversing the polarity of the applied direct voltage. A device can be provided having a radiation source at one side only as described above.

In the device shown in Figures 4*a* and 4*b* an electrophoretic suspension layer 44 includes a suspension medium 39 and at least two kinds of electrophoretic materials 45 and 46 in finely divided powder form; the two materials have the same charge polarity but different electrophoretic mobilities and luminescent properties. Initially, the device of Figure 4*a* has on both sides a luminescent colour which is a mixture of the luminescent colours of the two kinds of electrophoretic materials when subjected to radiation flux or alternating electric field. If the two materials emit, for example, yellow and blue light, respectively, the device shows white colour, the additive effect of the yellow and blue light, at both sides. With an applied direct electric field both types of electrophoretic material are caused to move electrophoretically in the same direction.

If electrophoretic materials 45 and 46 are positive and the electrophoretic mobility of the material 45 is greater than that of material 46, the material 45 moves faster than material 46 in the suspension layer under the effect of the electric field and a greater amount of the former material is deposited nearer the cathode, as indicated in Figure 4*b*. The device thus exhibits a yellow colour toward the cathode and a blue colour toward the anode. This is because the electrophoretic materials 45 and 46 are substantially opaque to radiation flux and/or visible light.

The colour of the display or display and recording device can be reversed by reversing the polarity of the applied direct voltage. It will be seen that in the embodiments of the invention so far described and illustrated, the luminescent electrophoretic suspension layer comprises a suspension medium and at least one electrophoretic material in a finely divided powder form suspended in the medium. The suspension layer can comprise a porous layer and/or another electrophoretic material which may have a different luminescent property, opposite charge polarity or different electrophoretic mobility from at least one of the electrophoretic materials. The electrophoretic suspension layer includes at least one luminescent component selected from the group consisting of a suspension medium, the electrophoretic material and a porous layer. The luminescent suspension layer emits visible light when the luminescent component in the suspension layer is excited by the radiation flux or electric field such as alternating pulse or pulsating electric field, applied thereto.

The luminescent property of the suspension layer is susceptible of control by a direct electric field applied to it: the applied field changes the spatial distribution of the electrophoretic material in the suspension medium electrophoretically so that the magnitude of the radiation flux for producing a given brightness of the luminescent component in the suspension layer changes and/or the light emitted from the luminescent component in the suspension layer changes in strength and/or spectral property before the light emerges from the device. The suspension layer, therefore, must comprise at least one component which is substantially opaque with respect to the radiation flux and/or the light emitted from the luminescent component in the suspension layer. The opaque component consists of at least one component, not including the one luminescent component, and may be selected from the group consisting of the suspension medium, the electrophoretic material and the porous layer. In Figures 1 to 4, if the device is observed from one side only, for example from the side of electrode 28, the housing wall 24 and the electrode 28 must be transparent with respect to visible light. When the suspension layer is excited so as to emit light in response to the radiation flux, it is further necessary that at least one of the housing walls 24 and 25, and the electrode adjacent that wall, should be transparent to the radiation flux. It is possible to construct devices of different type by directing the radiation source toward wall 24, that is, toward the front of the panel, or toward wall 25, that is, with the source behind the panel. In any arrangement, the wall and the electrode facing the radiation source must be transparent to the radiation flux.

In Figure 5, a suspension layer 50 can be any one of the possible luminescent electrophoretic suspension layers described such as layers 21, 37, 42 or 44. The layer 50 includes at least one electrophoretic material suspended in a suspension medium and is enclosed in a housing 22 having opposite major walls 24 and 25. The first electrode 51 carries a pattern, or symbol, shown as an E-shaped symbol. The second electrode 52 extends substantially uniformly across the entire wall 24. The device is intended to be observed only from the side of wall 24, and so wall 24 and the electrode 52 are made transparent to at least visible light. If the electrophoretic suspension layer 50 is electroluminescent, the device will display the symbol 'E' upon application of, for example, a sinusoidal alternating voltage.

or an alternating or direct pulse type voltage between electrodes 51 and 52. The colour of the 'E' can be changed for example by reversing the polarity of the applied direct voltage.

When the layer 50 emits light when excited by radiation flux; the device is provided with at least one radiation source, in front of or behind the panel, and the wall and electrode attached exposed to the radiation flux must be transparent to it. The colour characteristic of the symbol can be changed, while the suspension layer is exposed to radiation flux, by varying the magnitude, duration of application or polarity of the applied direct voltage.

The construction shown in Figures *6a* and *6b* includes a luminescent electrophoretic suspension layer 50 which can be any of ~~the~~ electrophoretic suspension layers described, such as layers 21, 37, 42 or 44. The layer includes at least one electrophoretic material suspended in a suspension medium and is enclosed in a housing 22 having two opposite major walls 24 and 25.

A first electrode 53 is composed of a plurality of separate segmental electrodes S_1—S_7. A second electrode 52 extends uniformly over the area of wall 24. The wall and electrode through which the device is observed are transparent to at least visible light. When layer 50 is exposed to radiation flux to cause it to emit light, the wall and adjacent electrode exposed to radiation flux must be transparent to the flux. Electrodes S_1—S_7 are connected through conductive leads to electrical terminals T_1—T_7 positioned on the exposed surface of the wall 5 as shown in Figure 6b. The electrodes S_1—S_7 provide a monogrammic device, so that different combinations of the electrodes S_1—S_7 can be used to present different numbers or characters when a direct electric field is applied across the selected segmental electrodes and the second electrode 52 while the suspension layer 50 is exposed to radiation flux. For example, a direct electric field applied across the electrode 52 and the segmental electrodes S_2, S_3, S_5, S_6 and S_7 will cause the device to display a formalised figure '3'.

In another method of connecting the segmental electrodes S_1—S_7 to the respective terminals, shown in Figure 6c, the electrodes are connected to electrical terminals located on the edges of the wall 25 by using leads L_1—L_7 formed on the same surface as the segmental electrodes. Other methods of making the necessary connections can be adopted.

The construction of Figure 7 includes a suspension layer 50 which can be any of the layers described such as layers 21, 37, 42 or 44 and as such includes at least one electrophoretic material suspended in a suspension medium, enclosed in a housing 22 having major walls 24 and 25.

A first electrode consists of a series of strip electrodes x_1, x_2, x_3, . . . which are parallel to each other and are attached to the inner surface of wall 24. A second electrode is attached to the inner surface of wall 25 and consists of a further series of strip electrodes y_1, y_2, y_3, . . . parallel to each other and at right angles to electrodes x_1, x_2, x_3 . . . .

If the device is to be observed through the wall 24 the wall 24 and the adjacent electrode must be transparent to visible light. When the suspension layer 22 is excited by the radiation flux so as to emit light, the device has at least one radiation source in front of or behind the panel. The ~~housing wall and~~ the electrode facing toward the radiation source are transparent with respect to the radiation flux.

A unidirectional electric field is applied between one electrode of the series x_1, x_2, x_3, . . . and one of the series y_1, y_2, y_3, . . . If, for example, voltage is applied between electrodes x_2 and y_3, that part of the suspension layer 50 at the intersection electrodes x_2 and y_2 is subjected to the field and forms one picture element. The narrower the strip electrodes, the smaller the picture elements thus formed.

More than one electrode can be selected from each series to enable a desired pattern of picture elements to be built up. Scanning techniques can be utilized to scan the picture elements sequentially and cyclically.

The desired series of strip or segmental electrodes as shown in Figures 5, 6 and 7, can be prepared by any suitable method, such as electrodeposition, vacuum evaporation, printing or photoetching techniques.

Another embodiment of the invention is shown in Figures *8a*, *8b* and *8c*. This includes a suspension layer 50, which can be any of the layers previously described. The layer includes at least one electrophoretic material suspended in a suspension medium and is enclosed in a housing 22 having spaced walls 55 and 56; at least one wall, in this case wall 55, consists of a sheet of an insulating material such as polyester, cellulose acetate, cellophane or polyethylene.

An electrode 57 is placed on the outer surface of the wall 55; it is not fixed to the surface of the wall and can be easily removed. The electrode is, however, coupled to the suspension layer 50. The second electrode can be, for example, a metal plate and as shown is constituted by the other wall 56 of the housing.

If the second wall has a high electrical resistance, a second electrode can take the form of a thin electrically conductive film

attached to the inner surface of the wall 56; again, it is also possible to use as the electrode, a metal plate on which the wall 56 is placed. If the wall 55 has a high electrical resistance, a higher value of direct voltage must be impressed between the electrodes.

The contact area of the first electrode 57 can be given a pattern, and when a direct electric field is applied corresponding patterns are produced on the surfaces of walls 55 and 56 due to the movement of the electrophoretic material, and this pattern will persist after removal of electrode 57. The wall of the housing through which the effect is observed must be transparent to visible light and the wall exposed to radiation flux must be transparent to it.

The electrode 57 can be a manipulable electrode, such as a pen-like electrode, capable of being moved freely over the surface of wall 55 and it is then possible to produce a desired pattern, or writing, on the surface of the wall by applying voltage between the pen electrode and electrode at 56, while the electrode 57 is moved.

The desired electric field across the suspension layer 50 can be produced by surface charging of the high resistance wall 55, using charged particles such as ions or electrons in a manner similar to that used in electrostatic recording.

To erase the electrostatic patterns, a roller having a conductive surface can be used, with alternating or direct voltage applied to it, the roller being moved over the insulating surface of the wall. Alternatively, positive or negative charged particles can be put on the surface of the wall to produce the erasing electric field.

It is preferred to insert between walls 55 and 56 a spacer such as a porous layer 58, as shown in Figure 8*b*, or a sheet 59 having a large number of projections, as shown in Figure 8*c*, particularly when the walls are of flexible material. Said spacer is substantially transparent to visible light and radiation flux and serves to keep the walls 55 and 56 apart, and preserve the desired thickness of layer 50 despite pressure applied to the wall of the housing, due to the pressure of the electrode 57 or to bending of the housing, where the electrophoretic suspension layer is in liquid form.

The spacer can be made from any sheet having pores or projections and suitable material is a screen made of nylon or Tetron: Tetron is a trade name of a polyester fibre available in Japan. The porous layer 35 in Figure 2a must be substantially opaque or luminescent, but the spacer 58 or 59 is substantially transparent and non-luminescent and may act as a mechanical spacer between major walls of the housing. The spacer can be merely inserted between the two walls, or one or both surfaces of the spacer can be attached to the surface of the adjacent wall. The spacer need not be inserted in a suspension layer which includes a porous layer such as 35, if that layer is capable of serving as a spacer between walls of the housing.

Another form of construction is shown in Figure 9. Housing 22 has an insulating wall 55 and a wall 25 to which is attached an electrode 29, connected to a voltage source 30. Wall 25 and electrode 29 are transparent to at least visible light. Housing 22 contains the electrophoretic suspension layer 50 and the housing is designed to form the front face of the envelope 60 of a cathode ray tube device.

The device includes an electron gun 61 and scanning means 62, by which negative electron charges ~~in a given~~ pattern can be deposited on the insulating surface of the wall 55. By modulating the beam intensity, for example in accordance with a video signal, the charge pattern built up will produce a corresponding electric field across the electrophoretic layer 50. When the suspension layer is exposed to radiation flux, visible patterns are reproduced on the walls 25 and 55 due to the movement of the electrophoretic material. Conveniently the radiation flux can be directed onto the suspension layer through a transparent window 63 in the envelope and through wall 55, or through the wall 25 and electrode 29. In the latter case, if the electrode 29 and wall 25 are transparent to radiation flux and to visible light, the window is not necessary. The first electrode 29 acts as an anode, and the electron gun 61 acts as a cathode. The visible pattern can be erased by a suitable secondary emission characteristic of wall 55.

In a modification of the display device shown in Figure 9 the wall 55 is replaced by a wire-mosaic faceplate consisting of a thin glass sheet having embedded therein a large number of fine transversely extending wires. This wire-mosaic provides the electrical connection between the electron beam in the vacuum and the electrophoretic suspension layer outside the vacum. The electron beam charges the wires of the mosaic and so applies an input electric field across the suspension layer.

Figure 10 shows an arrangement including the suspension layer 50 which can take any of the forms described. The layer includes at least one electrophoretic material suspended in a suspension medium and is applied to a base plate or sheet 65 which can be of material such as paper, metal or plastic. The base plate is placed on an electrode 66. Since the suspension layer is not confined within a housing, it must have high viscosity, but must be capable of being brought to a condition in which the re-

quisite degree of electrophoteric mobility is possible when voltage is applied. A suitable suspension layer may be in a solid state at room temperature but capable of being softened by a suitable method, such as heating or the addition of a solvent.

An electrode 57 is shaped to give a desired pattern of contact with the surface of the suspension layer. A direct electric field is applied between the electrodes so as to move the electrophoretic material electrophoretically while the suspension layer is softened by heat or by means of a solvent. The suspension layer is exposed to radiation flux and when thereafter the electrode 57 is removed the pattern remains on the surface of the suspension layer. If the base plate is transparent, a complementary pattern of different colour can be observed through the base plate. A permanent pattern can be produced by cooling the suspension layer or by evaporating the solvent as the case may be. If the base plate 65 is conductive, it may be used as the electrode, and a separate electrode 66 is not required.

The luminescent component in the luminescent electrophoretic suspension layer can be a fluorescent material of the type used in fluorescent lamps, scintillators, cathode ray tubes, radar or luminous paints.

The luminescent electrophoretic material can be organic or inorganic fluorescent materials in a finely divided powder form; fluorescent pigments or dyes can be used directly. Fluorescent material which can be used include material in the form of a main body consisting of the oxide, sulphide, selenide, silicate, phosphate or tungstate of metal such as calcium, barium, magnesium, zinc, cadmium or strontium. A small amount of manganese, silver, copper, antimony, lead or bismuth is added, as an activator, to the main body. Organic fluorescent materials which can be used include dyes such as diaminostilbene group, fluorescein, thioflavine, eosine or rhodamine B.

The luminescent appearance of the material refers to the intensity and/or spectral distribution and persistence of the light emitted from the luminescent material in response to radiation flux or electric field applied thereto. Suitable luminescent suspension medium can be prepared by dissolving the fluorescent dye in a liquid carrier or by suspending electrically neutral fluorescent material in finely divided powder form in a liquid carrier.

The luminescent porous layer can be prepared by using non-luminescent cloth, mesh or porous layer material, dyed or coated with fluorescent dye or pigment or by binding together fluorescent material in granular form, using resin or adhesive agent, to form a porous structure. The electrophoretic material need not be luminescent when the suspension medium or the porous layer is luminescent; non-luminescent electrophoretic material which can be used includes, for example, carbon black, graphite or titanium dioxide. Black pigment may be opaque due to absorption of visible light and white pigment may be opaque due to reflection of visible light.

An electrophoretic material suspended in a suspension medium usually has a charge which is positive or negative depending upon the properties of the electrophoretic material and the suspension medium.

The electrophoretic suspension layer 27 or 37 of Figures 1*a* or 2*a* can consist of a single electrophoretic material of either positive or negative polarity, suspended in a suspension medium. The electrophoretic suspension layer 42 or 44 of Figures 3*a* or 4*a* must include at least two kinds of electrophoretic materials suspended in the medium. These two kinds of electrophoretic materials must have different luminescent properties, and different charge polarities or electrophoretic mobilities. Accordingly, in preparing an electrophoretic suspension layer such as 42 or 44, at least two electrophoretic materials having suitable luminescent properties and electrophoretic properties must be selectively suspended in the suspension medium.

The suitable average particle sizes of the finely divided particles depend upon the stability of the resultant electrophoretic suspension, and lie usually in the range from 0.1μ to 50μ.

It is advantageous to add a suitable charge control agent, dispersion agent or stabilizing agent to the electrophoretic suspension layer in order to provide a stable suspension layer. To control the charge property of the suspended particles, it is preferred to use particles coated with a resin which is not soluble in, or only partially soluble in, the suspension medium. If the coating resin is partially soluble in the suspension medium, it can also act as a fixing agent for a displayed image.

There can be used, as a suspension medium any suitable liquid which is inert to the electrophoretic material, the porous layer, the housing and the electrode. For producing a temporary display there can be used as a suspension medium in a liquid state at room temperatures, that is from 0°C to 35°C. Suitable suspension media include, for example, kerosene, trichlorotrifluoroethane, isopropyl alcohol, mineral oil, liquid paraffin or olive oil. For producing a permanent display, that is, a permanent or semi-permanent copy, the suspension medium may be one which is in a solid state at room temperature but can be rendered fluid or liquid above room temperatures, that is, above 35°C. Such media

include, for example, waxes such as beeswax vegetable wax, paraffin or synthetic wax.

When using these waxes and similar materials, the device, or at least the suspension layer, must be kept at a suitable temperature above room temperature, for recording the display. After the device has been subjected to the direct electric field at the higher temperature and the spatial distribution of the electrophoretic material, varied electrophoretically, the device is cooled to room temperature to produce a permanent display. If it is desired to erase such a display, the device is subjected to an alternating or direct electric field at the higher temperature. Once the material of the suspension layer has hardened, an electric field applied to the electroluminescent suspension layer to render it visible does not change the distribution of the electrophoretic material and the permanent image is retained.

The suspension medium may consist of a thermosettable material which is in a liquid state at room temperature; a completely permanent display is then obtained by producing the desired distribution of the electrophoretic material and then setting the medium by the application of heat.

Thermosetting materials which can be used as suspension media in this way include, for example, drying oil such as linseed oil, soya oil or tung oil. The liquid suspension medium may include a binder such as polystyrol, vinyl acetate resin or linseed oil which fixes the electrophoretic material in a finely divided powder form, and a hard copy having a permanently visible image reproduced thereon can be obtained by evaporating or extracting the residual medium. The evaporation or extraction of the medium can be effected by reduced pressure applied to the medium, for example, by evacuating the housing including electrophoretic material in the suspension medium through an outlet formed in a wall of the housing.

Suitable housings can be made of any available material which is inert to the suspension medium and the electrophoretic material. For example, the frame 23 can be formed from a plastic sheet having a central opening. One of the two walls can be provided with a metal plate secured by adhesive to the frame: such a plate may serve as one electrode as described. The other wall can be provided by a transparent glass plate secured to the frame by adhesive, the plate having on it a transparent conductive thin film such as a film of tin oxide, cuprous iodide or metal. The transparent conductive thin film is in contact with the electrophoretic suspension layer. To provide a device with a radiation source located behind the panel the metal plate can be replaced by a second transparent glass plate with a conductive film on it. These methods of construction are given by way of example only, and any of a variety of methods can be adopted.

In assembling the device the electrophoretic suspension can be introduced by providing a housing with only one major wall attached, pouring in the suspension and then attaching the closing wall, or the housing can be completed but for an inlet in one wall through which the suspension is poured, and the inlet closed when the housing has been filled.

Improved operating life can be obtained by coating at least one of the electrodes with an insulating layer in contact with the suspension layer. This insulating layer improves the resistance of the suspension layer to electrical breakdown and permits the use of higher electric voltage. The layer also makes it easier to remove the electrophoretic material from the electrode surface when forming a new image by subjecting the device to the appropriate electric field.

Figure 11 shows an example of a construction using an insulating layer: a first electrode 28 is coated with an insulating layer 70 which is insoluble in the suspension medium. The other electrode 29 or both electrodes can be so coated with insulating material. The insulating layer can be provided by coating the electrode with, for example, vinyl acetate resin, polystyrol or gelatin, which forms a transparent insulating layer suitable for a transparent wall of the housing. The thickness of the layer 70 depends on the electrical resistance which it is desired that the layer and the electrophoretic suspension layer 22 should have. For operation at a low voltage it is desirable that the insulating layer 70 should have an electrical resistance no greater than that of the suspension layer 22.

The suspension layer can be divided to present a series of individual cells or chambers, nested to form a composite layer. For example, as shown in Figure 12a the suspension layer 50 is split up by a plurality of spacers 71 extending traversely of the layer so as to present a number of cells 72 each containing the suspension. The spacers can be provided by a sheet of material 73 having holes therein, as shown in Figure 13, used so as to divide the suspension layer into separate chambers or cells.

The cells, formed by holes 74 or otherwise, can have any suitable shape, such as square, as shown in Figure 13, circular, rectangular, hexagonal, and so on. The cells can be regular or irregular in shape and may vary widely in dimension and disposition or order. The dimensions of the cells are selected in accordance with the desired

display or the nature of the suspension, or both, but the cells must be at least greater than the dimensions of the particles of electrophoretic material in the suspension.

By dividing the suspension layer into a plurality of cells or units a more uniform or sharply defined display can be produced because movement of the electrophoretic material is confined to the limits of each cell. Suspension material in different cells of the same assembly may emit light of different colour. The suspension units are preferably disposed between electrodes, one of which has a plurality of segment electrodes as shown at E_1, E_2, E_3, ... in Figure 12b corresponding to and in contact with the suspension in the individual cells, the other electrode being transparent and extending over the transparent wall 24 of the housing, also as shown in Figure 12b. If the cells are very numerous, the electrode E_1, E_2, E_3, etc. can be formed as dots. In this way, each cell with its portion of the suspension layer between an electrode segment and the common electrode forms an individually controllable picture element Each cell can be caused to produce a colour image by applying a direct viltage between the common electrode 28 and the selected segment electrode while the suspension layer units are exposed to radiation flux.

One way to provide electrodes for a number of such cells which are in an orderly pattern is to provide a first electrode structure consisting of a plurality of strip electrodes parallel to each other and a second electrode consisting of a plurality of strip electrodes which are disposed at right angles to the strips of the first electrode, similar to the arrangement shown in Figure 7. The cell located at each intersection of a strip of the first electrodes and a strip of the second electrodes can then be selectively activated, and can be used as a picture element. The cells can then, by use of a suitable suspension, be arranged to emit different colour light, for example red light as at 50R, green light as at 50G, or blue light as shown at 50B in Figure 12c. The production of a suitable electric field by appropriate voltages impressed on the electrodes can be arranged to cause selected picture elements to reproduce a luminescent coloured image on the display panel.

A display panel for producing a colour image can be provided by using mosaic colour filters and a suspension capable of changing in shades of grey between black and white; areas of the transparent wall of the housing or the transparent electrode corresponding to each picture element in a display panel of the type shown in Figures 7 or 12b are selectively coloured so that it acts as a colour filter, for example, for red, green or blue. However, a display device having at least three kinds of suspensions, that is red, green and blue, gives a better colour rendering, especially with respect to the brightness of the high lights, than can a panel with the mosaic colour filter on the transparent wall or electrode.

A monogrammatic character display panel, similar to that described with reference to Figure 6, can also be formed by a series of individual units each corresponding to one of the segmental electrodes shown.

It is not necessary that the suspension layer should be defined by plane surfaces, and curved surfaces can be used. For example, in Figure 14, the suspension layer 50 is enclosed in a housing consisting principally of two concentric cylinders 75 and 76. The inner cylinder 75 carries an electrode ~~79 and cylinder 76 an~~ electrode 78 attached thereto. Electrodes 79 and 78 are similar in nature to electrodes 52 and 53. The cylinder 75 can be constructed to enclose a gas such as, for example, argon or krypton and mercury capable of sustaining a gas discharge. With the gases mentioned, ultra-violet radiation, mainly at 2537Å, is emitted if an electric field is applied to the gas in conditions to cause a suitable discharge.

The inner cylinder and the electrode attached to the outer surface of the cylinder are transparent to the radiation flux. The outer cylinder and the electrode on its inner surface are transparent to visible light. A direct voltage from a voltage source 30 is applied between the electrodes so as to control the spatial distribution of the electrophoretic material of the suspension and thereby the luminescent appearance of the device. The source 30 can supply not only the direct voltage but also said electric field, such as an alternating field for producing the gas discharge. The inner surface 101 of the inner cylinder can have upon it a coating of fluorescent material to convert the light in the ultra-violet spectrum from the gas discharge into radiation in other parts of the spectrum. The device in Figure 14 is useful as a fluorescent lamp, the colour of which can be changed by varying the intensity, duration time of application and the polarity of applied direct voltage.

The amount of electrophoretic material in a suspension medium or the thickness of the electrophoretic suspension layer is selected, depending upon the opacity, luminescent property or electrophoretic property of the electrophoretic material, the range of colour change required in the device, feasibility of the voltage souce and so on.

Since the display devices described are of the luminescent type, a component of the suspension layer must be opaque with respect to the radiation flux and/or visible

light in order to make an adequate colour change. The thicker the suspension layer, the higher the applied voltage usually required. The thinner the suspension layer, the greater the concentration of electrophoretic material required for a given colour change. The thickness of the suspension layer in practical devices is usually in the range from a few microns to a few mm.

The following are examples of suitable material.

EXAMPLE 1

Ten grams of Cyanine green B particles, which is phthalocyanine green supplied by Dainippon Ink Chemical Industrial Company in Japan, were added to 100 ml of olive oil and blended well in a ball mill to produce a first paste. The first paste was deep green in colour when viewed in white light. The green particles had negative charge polarity in olive oil. Ten grams of a fluorescent powder particles supplied as EL-GSL by Sakai Chemical Industrial Company in Japan in a main body of zinc sulphide were added to 50 ml of olive oil and mixed well by ultrasonic vibration to produce a second paste. The second paste had a faint green colour when viewed in white light. The zinc sulphide particles had weak positive charge polarity and did not show any noticeable electrophoresic activity in olive oil. Equal volumes of the first and the second pastes were mixed well to produce a third paste. The third paste was placed between an aluminium plate and an EC glass electrode so to produce a luminescent electrophoretic suspension layer having a thickness of 100μ. The EC glass was a transparent glass plate having a transparent conductive layer of tin oxide thereon. The suspension layer radiated yellowish green light through the EC glass electrode when the suspension layer was exposed, through the EC glass electrode, to ultra-violet radiation flux from a black light lamp. When a direct voltage of 300 V was applied between the EC glass electrode as cathode and the aluminium plate as anode, the luminescent colour of the suspension layer changed and became bright green. When the polarity of the applied voltage was reversed, the colour of the suspension layer became deep green. The luminescent green colour of the suspension layer could be changed in brightness by varying the voltage, time of application or polarity of the applied voltage. The displayed colour could be maintained after the removal of the applied field. The reflective colour characteristic of the suspension layer could also change its green colour on application of a direct voltage when viewed under white light. The zinc sulphide particles used were electroluminescent and the suspension layer radiated electroluminescent light on application of an electric field.

A direct voltage of 300 V was applied between the EC glass electrode as cathode and the aluminium plate as anode. After that, when a sinusoidal alternating voltage of 250V at 1 kHz was applied between the two electrodes, the suspension layer emitted a bright green light through the EC glass. When the sinusoidal voltage was applied between the two electrodes after application of a direct voltage of reverse polarity, the suspension layer was deep green. As mentioned above, the suspension layer in this example radiated visible light when ultraviolet light or an alternating electric field was applied to it. The cell was useful as a colour change panel in which green brightness could be controlled.

EXAMPLE 2

Ten grams of fluorescent powder particles supplied as EL-RI by Dainippon Paint Company in Japan, in a main body of zinc sulphide was added to 50 ml of toluene dissolved ten grams of vinyl acetate resin therein and mixed well by application of ultrasonic vibration to produce a paste.

The surface of screen sheet No. 1000 supplied by the Teijin Company of Japan and woven of polyester fibre was coated with the paste to produce a luminescent porous layer. The porous layer emitted red light when exposed to ultraviolet light from a black light lamp. Five grams of the fluorescent powder particles as used in Example 1 were added to 50 ml of isopropyl alcohol and mixed well by an ultrasonic vibrator to produce a suspension. The powder particles had negative charge polarity in isopropyl alcohol. The luminescent porous layer was inserted between two screen sheets No. 1350 supplied by Teijin Company of Japan to produce a sandwich; a housing was fashioned by inserting the sandwich between an EC glass electrode and an aluminium plate, and the housing was filled with the suspension to produce a luminescent electrophoretic suspension layer. The housing was made liquid-tight by an adhesive agent. When the suspension layer was exposed, through the EC glass electrode, to ultra-violet light from a black light lamp, the suspension layer emitted yellow light. When a direct voltage of 25V was applied between the EC glass electrode as anode and the aluminium plate as cathode, the luminescent colour of the suspension layer was green under ultra-violet light. Application of a direct voltage of reverse polarity between the EC glass electrode and the aluminium plate changed the luminescent colour of the suspension layer from green, through yellow, to red. A sinusoidal

alternating voltage of 150 V and 60 Hz was half-wave rectified by a rectifier so as to produce repeated unidirectional pulses of voltage and when this pulse voltage was applied between the EC glass electrode and the aluminium plate, the suspension layer emitted electroluminescent orange light when the EC glass electrode was the cathode and green light when the glass was the anode.

The device of this example was useful as an electric colour changeable panel capable of being altered in colour from green, through yellow, to red and vice versa under excitation by ultraviolet light.

Attention is directed to our co-pending Applications 19611/70 and 19612/70 (Serial Nos. 1,313,412, 1,313,413) which contain claims directed respectively to devices and to methods of operating devices utilizing electrophoretic movement.

WHAT WE CLAIM IS:—

1. A display device comprising a layer, including a luminescent material, the luminescent appearance of the device being controllable by electrophoretic movement of an electrophoretic material in said layer.

2. A display device in accordance with claim 1, wherein said electrophoretic material is luminescent.

3. A display device in accordance with claims 1 or 2, and comprising a luminescent non-electrophoretic material.

4. A display device comprising a layer including a suspension medium and at least one material in a form susceptible of electrophoretic mobility suspended in said medium, at least one of the components of said layer being luminescent material, and at least one of the components of said layer being substantially opaque to the radiation which excites the luminescence or to visible light emitted by the luminescent component, said suspension being bounded by opposed surfaces, spaced electrodes positioned with respect of said surfaces whereby on applying an electric field across said layer between said electrodes, the spatial distribution of said electrophoretic material between said surfaces is electrophoretically changed whereby to change the luminescent appearance of said device.

5. A display device in accordance with claim 4, wherein said surfaces are generally parallel.

6. A display device in accordance with claim 5, wherein electrodes are positioned to impose on said suspension a field which is substantially at right angles to the said surfaces.

7. A display device in accordance with claims 4, 5 or 6, wherein at least one electrode is positioned on one of said surfaces.

8. A display device in accordance with any of claims 4 to 7 wherein a wall member defining at least one of said surfaces is transmissive to energy for exciting said luminescent material.

9. A display device in accordance with any of the preceding claims, wherein said luminescent material is capable of being rendered luminous by electromagnetic radiation.

10. A display device in accordance with claim 9, wherein said radiation is in the non-visible spectrum.

11. A display device in accordance with claim 10, wherein said radiation is in the ultra-violet range.

12. A display device in accordance with any of the claims 4 to 8, wherein said radiation is energy from a radioactive source.

13. A display device in accordance with claim 12, wherein said source is an embodied part of said display device.

14. A display device in accordance with claim 13, wherein said source is in said suspension.

15. A display device in accordance with claims 12, 13 and 14, wherein said energy is radiation from a radioactive isotope of radium, strontium 90, tritium or promethium 147.

16. A display device in accordance with any of claims 4 to 15 comprising means for applying a voltage between said electrodes.

17. A display device in accordance with claim 16, and comprising means for impressing an alternating electric field on said layer.

18. A display device in accordance with claim 16, and comprising means for impressing a repetitive uni-directional pulse field on said layer.

19. A display device in accordance with any of claims 4 to 18, wherein at least said electrophoretic material is luminescent.

20. A display device in accordance with any of the preceding claims and comprising at least two electrophoretic materials, which differ in charge polarity.

21. A display device in accordance with any of claims 1 to 19, and comprising at least two electrophoretic materials, which differ in electrophoretic mobility.

22. A display device in accordance with any of the preceding claims, and comprising at least two electrophoretic materials which differ in luminescent properties.

23. A display device in accordance with any of claims 4 to 22 wherein said suspension medium is luminescent.

24. A display device in accordance with any of claims 4 to 23 and comprising a porous layer inserted in said suspension medium.

25. A display device in accordance with claim 24 wherein said porous layer is luminescent.

26. A display device in accordance with any of claims 4 to 25, wherein said suspension further contains a binder for said electrophoretic material, which binder is at least partially soluble in said suspension medium.

27. A display device in accordance with any of claims 4 to 26, wherein said suspension medium is a hardenable material.

28. A display device in accordance with claim 27, wherein said suspension medium is heat hardenable.

29. A display device in accordance with any of claims 4 to 26 wherein said suspension medium is heat softenable.

30. A display device in accordance with any of claims 4 to 29, and including means for applying an electric field to said suspension and means for controlling said electric field as to intensity and/or duration and/or polarity.

31. A display device in accordance with any of the claims 4 to 30, and including a housing enclosing said layer, said housing presenting two spaced opposed major housing walls between which said suspension layer and said electrodes are positioned.

32. A display device in accordance with claim 31, wherein at least one wall and the adjacent electrode are transparent to visible light.

33. A display device in accordance with claim 32, wherein one electrode and the adjacent wall is transparent to energy, or radiation, inducing luminescence, and the other electrode and the other wall is transparent to visible light.

34. A display device in accordance with claim 33, wherein one of said walls is transparent with respect to said energy or radiation and has one electrode attached thereto, and the other of the walls is transparent with respect to visible light and has a second electrode attached thereto.

35. A display device in accordance with claim 32, wherein one of said walls and an adjacent electrode is transparent with respect to both said radiation and visible light.

36. A display device in accordance with any of claims 4 to 35, wherein at least one of said electrodes is in the shape of a desired pattern for display.

37. A display device in accordance with any of claims 4 to 35, wherein at least one of said electrodes is formed as a series of independent electrodes disposed on a common surface.

38. A display device in accordance with claim 37, wherein said electrode is formed as a series of substantially parallel strips of electrode material.

39. A display device in accordance with claim 38 wherein the other electrode is formed as a series of substantially parallel strips of electrode material.

40. A display device in accordance with claims 38 and 39, wherein the strips of the respective series are disposed substantially at right angles.

41. A display device in accordance with claim 37, and comprising means to define individual bodies of suspension pertaining to and controllable by said independent electrodes.

42. A display device in accordance with claim 41, wherein said individual bodies of suspension have different luminescent properties.

43. A display device in accordance with any of claims 4 to 42, wherein at least one said electrodes is provided with an insulating layer in contact with said suspension.

44. A display device in accordance with claim 32 wherein said transparent housing wall or said transparent electrode has a mosaic of colour filters thereon.

45. A display device in accordance with any of claims 4 to 44 and comprising cylindrical inner and outer walls confining said suspension.

46. A display device in accordance with claim 45, wherein the interior of said inner wall contains a gas, and comprising means for producing a luminous electric discharge in said gas.

47. A display device in accordance with any of the claims 4 to 46, said device being in association with an electron beam device, the beam current of which is adapted to control the electric field existing across said layer.

48. An improved display device, substantially as described, with reference to the accompanying drawings.

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1314906 COMPLETE SPECIFICATION

6 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

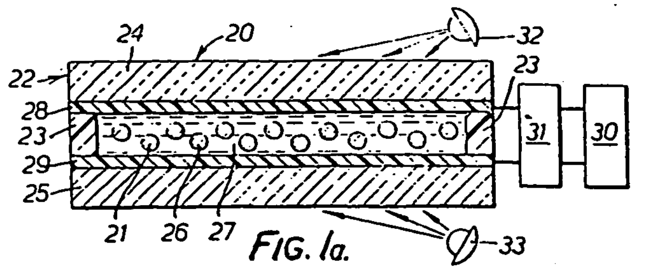

FIG. 1a.

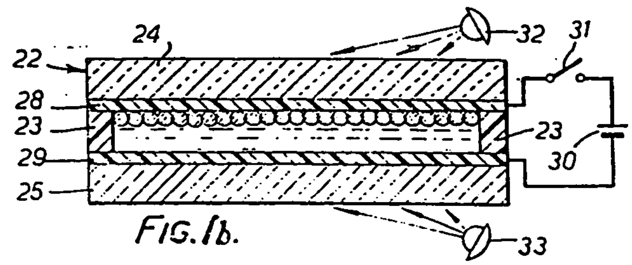

FIG. 1b.

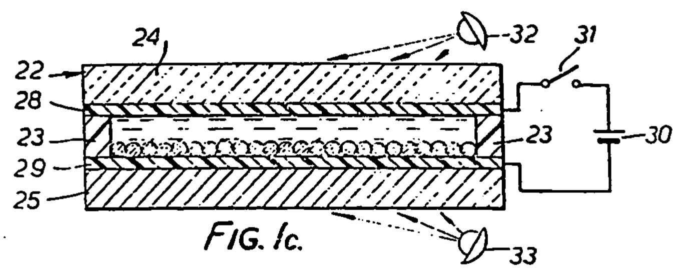

FIG. 1c.

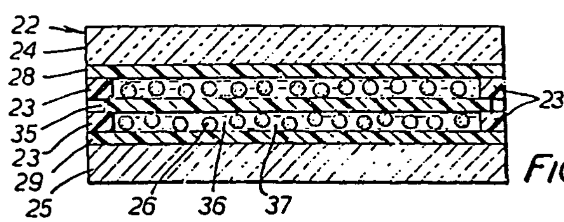

FIG. 2a.

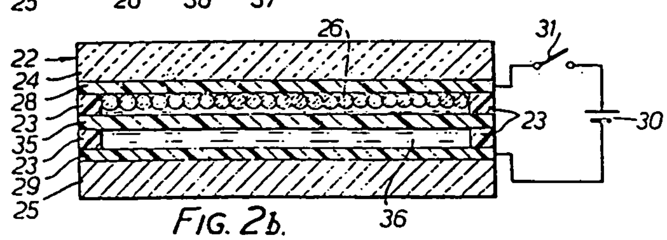

FIG. 2b.

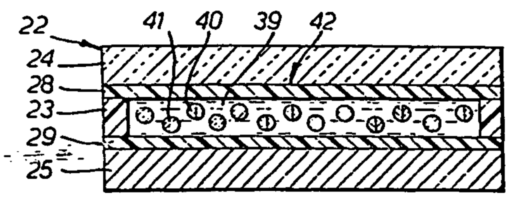

FIG. 3a.

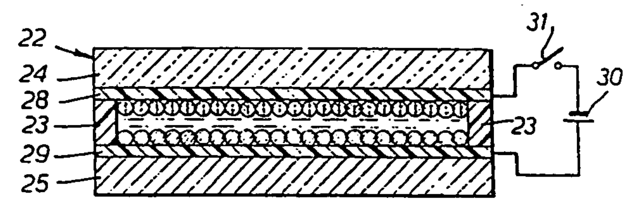

FIG. 3b.

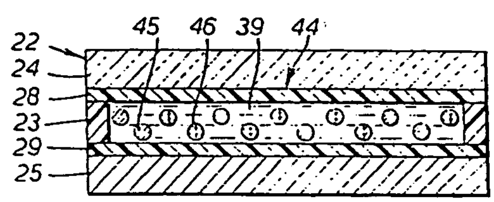

FIG. 4a.

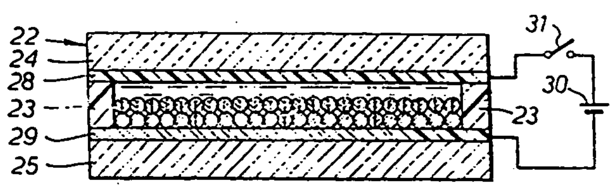

FIG. 4b.

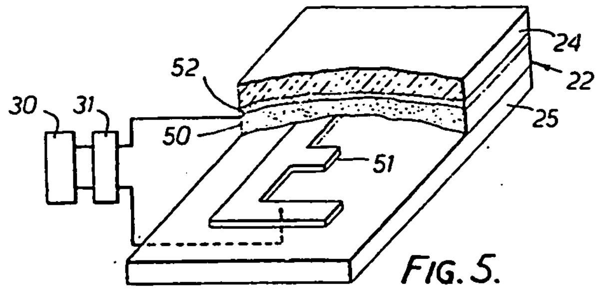

FIG. 5.

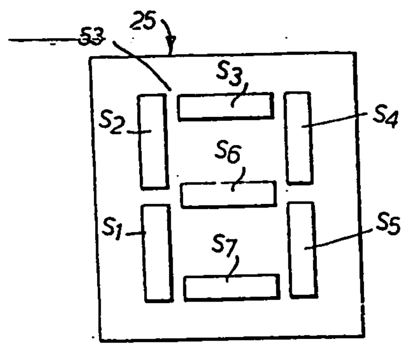

FIG. 6a.

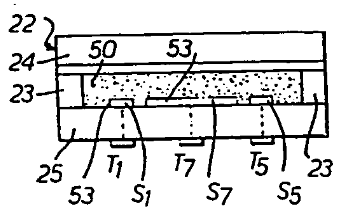

FIG. 6b.

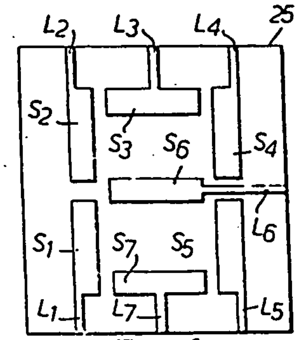

FIG. 6c.

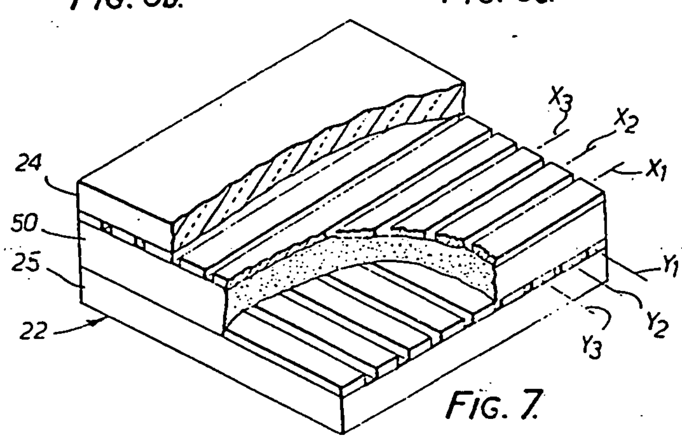

FIG. 7.

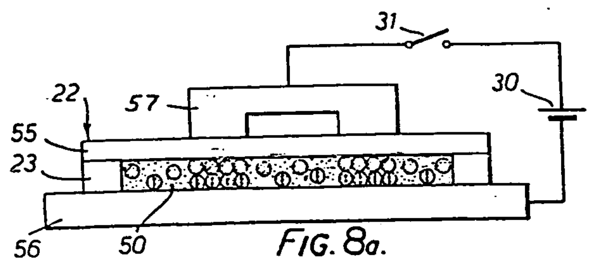

FIG. 8a.

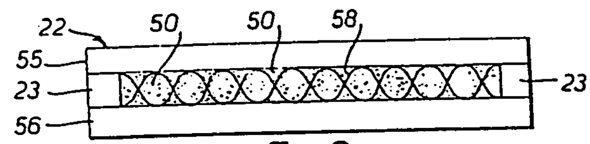

FIG. 8b

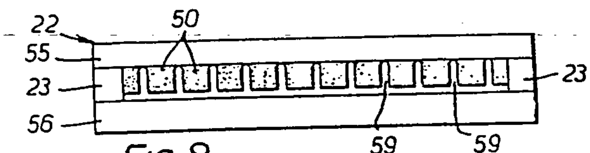

FIG. 8c

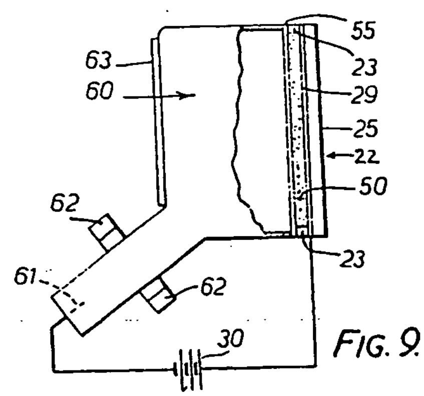

FIG. 9.

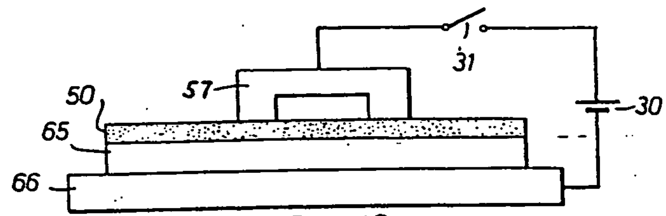

FIG. 10.

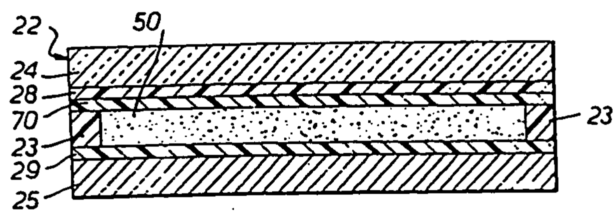

FIG. 11.

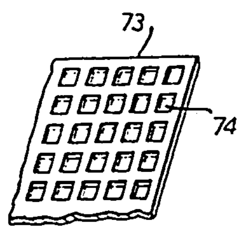

FIG. 13.

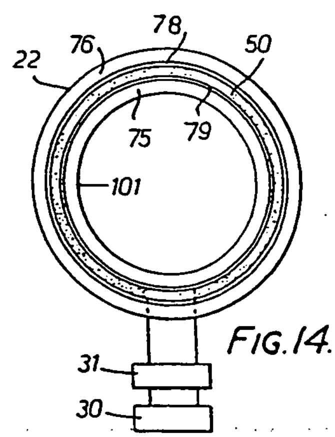

FIG. 14.

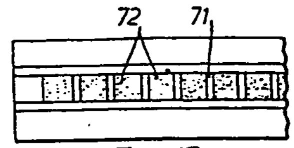

FIG. 12a.

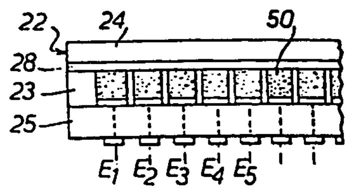

FIG. 12b.

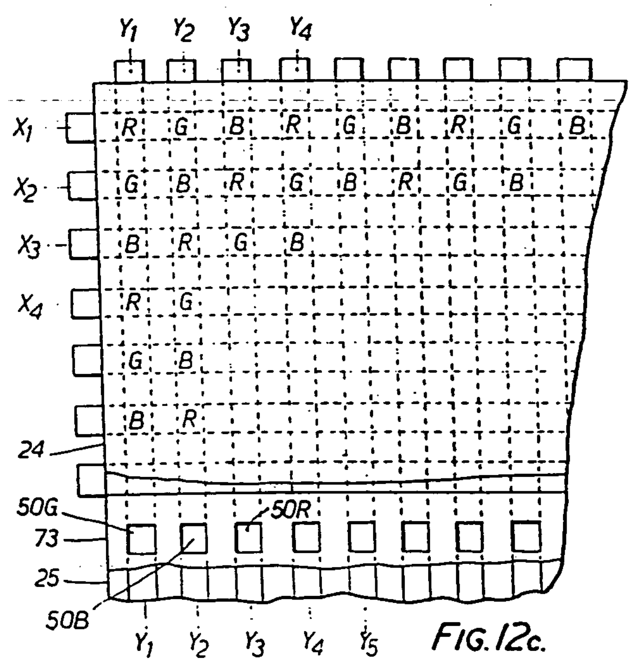

FIG. 12c.